S19 Final Review Session

Example Problems

Doppler Shift

A student on a bicycle approaches a brick wall as the student sounds a horn at a frequency 400 Hz. The sound he hears reflected back from the wall is at a frequency 408 Hz. At what is the speed is the student riding the bicycle toward the wall?

Discontinuities on a string

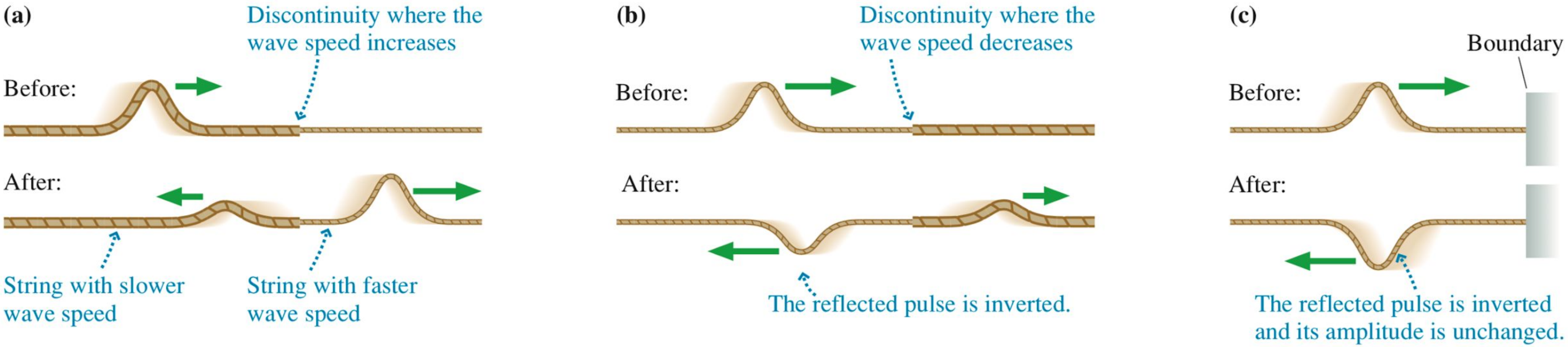
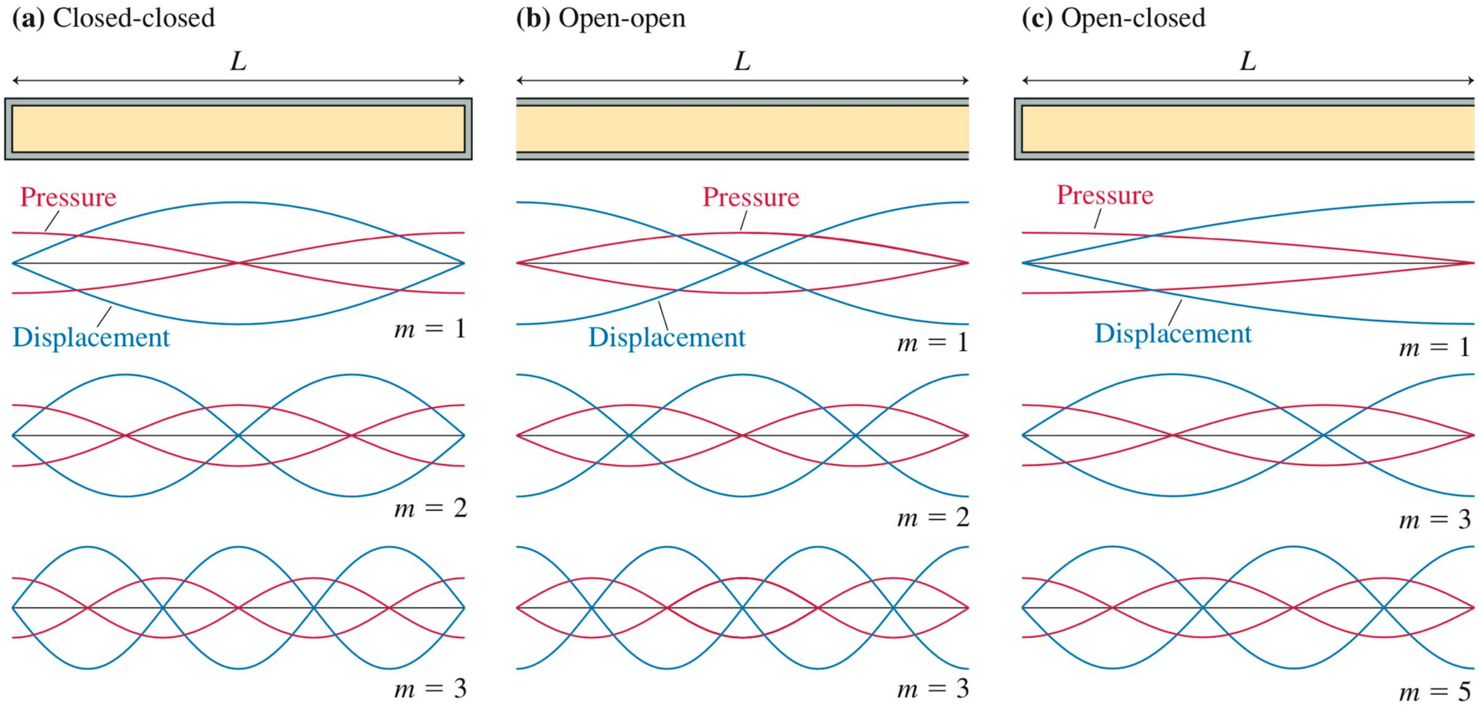


FIGURE 21.8 A wave reflects when it encounters a discontinuity or a boundary.

Standing Waves

FIGURE 21.18 The first three standing sound wave modes in columns of air with different boundary conditions.



Interference

A heavy stone of mass m is hung from the ceiling by a thin 8.25 g wire that is 65.0 cm long. When you gently pluck the upper end of the wire a pulse travels down the wire and returns 7.85 ms later, having reflected off the lower end. The stone is heavy enough to prevent the lower end of the wire from moving. What is the mass of the stone?

Beats

Two in-phase loudspeakers are some distance apart. They emit sound with a frequency of 1536 Hz. You move between the speakers, along the line joining them, at a constant speed of 2.8 m/s. What beat frequency do you observe?

Heat vs. Temperature vs. Thermal Energy

Heat, Temperature, and Thermal Energy

It is important to distinguish among *heat, temperature,* and *thermal energy.* These three ideas are related, but the distinctions among them are crucial. In brief,

- Thermal energy is an energy *of the system* due to the motion of its atoms and molecules. It is a *form* of energy. Thermal energy is a state variable, and it makes sense to talk about how E_{th} changes during a process. The system's thermal energy continues to exist even if the system is isolated and not interacting thermally with its environment.
- Heat is energy transferred *between the system* and the environment as they interact. Heat is *not* a particular form of energy, nor is it a state variable. It makes no sense to talk about how heat changes. $Q = 0$ if a system does not interact thermally with its environment. Heat may cause the system's thermal energy to change, but that doesn't make heat and thermal energy the same.
- Temperature is a state variable that quantifies the "hotness" or "coldness" of a system. We haven't given a precise definition of temperature, but it is related to the thermal energy *per molecule.* A temperature difference is a requirement for a thermal interaction in which heat energy is transferred between the system and the environment.

It is especially important not to associate an observed temperature increase with heat. Heating a system is one way to change its temperature, but, as Joule showed, not the only way. You can also change the system's temperature by doing work on the system or, as is the case with friction, transforming mechanical energy into thermal energy. **Observing the system tells us nothing about the process by which energy enters or leaves the system.**

Calorimetry

TABLE 16.3 Monatomic and diatomic gases

Monatomic		Diatomic	
He	Helium	H_2	Hydrogen
Ne	Neon	N_2	Nitrogen
Ar	Argon	O_2	Oxygen

TABLE 17.3 Melting/boiling temperatures and heats of transformation

Substance	T_m (°C)	L_f (J/kg)	T_b (°C)	L_v (J/kg)
Nitrogen (N_2)	−210	0.26×10^5	−196	1.99×10^5
Ethyl alcohol	−114	1.09×10^5	78	8.79×10^5
Mercury	−39	0.11×10^5	357	2.96×10^5
Water	0	3.33×10^5	100	22.6×10^5
Lead	328	0.25×10^5	1750	8.58×10^5

TABLE 17.2 Specific heats and molar specific heats of solids and liquids

Substance	c (J/kg K)	C (J/mol K)
Solids		
Aluminum	900	24.3
Copper	385	24.4
Iron	449	25.1
Gold	129	25.4
Lead	128	26.5
Ice	2090	37.6
Liquids		
Ethyl alcohol	2400	110.4
Mercury	140	28.1
Water	4190	75.4

Calorimetry #1

Heat is added to a 2.0 kg piece of ice at a rate of 793 kW. How long will it take for the ice to melt if it was initially at 0°C?

Calorimetry #2

Your 300 mL cup of coffee is too hot to drink when served at 90°C. What is the mass of an ice cube, taken from a -20°C freezer, that will cool your coffee to a pleasant 60°C?

- Assume coffee has the same specific heat as water (4190 J/(kg K) and the same density as water (1000 kg/m^3)

Root-Mean-Square Speed

At what temperature do hydrogen molecules have the same rms speed as nitrogen molecules at 100°C?

Summary of Ideal Gas Processes

TABLE 19.1 Summary of ideal-gas processes

Process	Gas law	Work W_s	Heat Q	Thermal energy
Isochoric	$p_i/T_i = p_f/T_f$	0	$nC_V \Delta T$	$\Delta E_{th} = Q$
Isobaric	$V_i/T_i = V_f/T_f$	$p \Delta V$	$nC_P \Delta T$	$\Delta E_{th} = Q - W_s$
Isothermal	$p_i V_i = p_f V_f$	$nRT \ln(V_f/V_i)$ $pV \ln(V_f/V_i)$	$Q = W_s$	$\Delta E_{th} = 0$
Adiabatic	$p_i V_i^\gamma = p_f V_f^\gamma$ $T_i V_i^{\gamma-1} = T_f V_f^{\gamma-1}$	$(p_f V_f - p_i V_i)/(1-\gamma)$ $-nC_V \Delta T$	0	$\Delta E_{th} = -W_s$
Any	$p_i V_i/T_i = p_f V_f/T_f$	area under curve		$\Delta E_{th} = nC_V \Delta T$